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APPARATUS AND METHOD FOR LATENCY CONTROL IN A COMMUNICATIONS SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application Serial Number 60/425,732 of Greenfield et al., filed November 13, 2002, entitled "Communications Systems and Method of Operation Thereof," the disclosure of which is hereby incorporated herein by reference as if fully set forth.

TECHNICAL FIELD

This invention relates to communications systems, and in particular to adaptive rate communications systems that suffer time varying noise conditions, such as Annex C ADSL (Asymmetric Digital Subscriber Line) systems.

BACKGROUND OF THE INVENTION

Annex C ADSL operates over twisted pairs that are bundled with Japanese ISDN-carrying twisted pairs. Fig. 1 is a plot depicting TCM (Time Compression Multiplex)-ISDN crosstalk noise. The crosstalk noise 101 generated by the ISDN twisted pairs is time varying, and is synchronous to a clock, called a TTR clock, having a time period 102. The TTR clock is an example of a noise clock.

Unlike an Annex C ADSL system, an Annex A ADSL system has no means of synchronization to a TTR clock and, indeed, cannot handle a time varying noise source. Thus all computations in an Annex A ADSL system such as the

computations used for the derivation of equalizers (gain adjust, bit allocation, etc.) are based on a continuous average measure of the noise environment.

By contrast, an Annex C ADSL system implements two different receivers, each optimized to the characteristics of its associated noise phase. While Annex C ADSL adapts better to time varying noise than Annex A ASDL, a drawback with Annex C ASDL is that the instantaneous bit rate varies in each phase. In order to achieve a constant bit rate, significant buffering is needed, which causes latency added to the data transmission. In some applications, the additional latency is unacceptable. Thus a fallback position is to use an Annex A ASDL solution, where disadvantages in handling time varying noise are to be expected.

SUMMARY OF THE INVENTION

In one variant, the present invention provides a method for controlling transmission latency in a communications system in which the communications system is subject to a noise signal having at least a first noise phase and a second noise phase. The method includes determining a first bit rate for symbols transmitted during the first noise phase, and a second bit rate for symbols transmitted during the second noise phase, the first bit rate and the second bit rate being constrained such that a transmission latency does not exceed a pre-determined maximum allowed transmission latency; and transmitting symbols at the first bit rate during the first noise phase and at the second bit rate during the second noise phase.

In another variant, the invention provides an apparatus which includes a constrained rate receiver for determining a first bit rate for symbols transmitted during the first noise phase, and a second bit rate for symbols transmitted during the second noise phase, the first bit rate and the second bit rate being constrained such that a transmission latency does not exceed a pre-determined maximum al-

lowed transmission latency; and, a constrained rate transmitter for transmitting symbols at the first bit rate during the first noise phase and at the second bit rate during the second noise phase.

In yet another variant, the invention provides a constrained rate receiver that is adapted to determine a first bit rate for symbols transmitted during the first noise phase, and a second bit rate for symbols transmitted during the second noise phase, the first bit rate and the second bit rate being constrained such that a transmission latency does not exceed a pre-determined maximum allowed transmission latency.

In yet a further variant, the invention provides a signal in a communications system, wherein the communications system is subject to a noise signal having at least a first noise phase and a second noise phase. The signal includes a determined first bit rate for symbols transmitted during the first noise phase, and a second bit rate for symbols transmitted during the second noise phase, the first bit rate and the second bit rate being constrained such that a transmission latency does not exceed a pre-determined maximum allowed transmission latency; and, symbols transmitted at the first bit rate during the first noise phase and at the second bit rate during the second noise phase, such that the transmission latency in the communications system can be controllable.

These and other variants of the invention are described in the accompanying drawings and remainder of the specification and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plot depicting TCM (Time Compression Multiplex)-ISDN crosstalk noise;

Fig. 2 shows a communications system with a constrained rate receiver for determining constrained bit rates for controlling transmission latency, in accordance with an embodiment of the invention;

Fig. 3 shows a constrained rate receiver for determining bit rates and bit allocation tables based on a signal-to-noise ratio and a maximum allowed transmission latency, in accordance with an embodiment of the invention;

Fig. 4 is a schematic diagram illustrating a time variant bit rate;

Fig. 5 is a schematic diagram of a buffer dynamic;

Fig. 6 is a plot showing Annex A ADSL and Annex C ADSL Bit rate computation in the presence of TCM(Time Compression Multiplex)-ISDN noise;

Fig. 7 is a plot showing spectral properties of NEXT, FEXT and averaged TCM-ISDN noise; and

Fig. 8 shows simulation results of loop length against bit rate for varying rate converter latencies in the presence of ISDN noise.

DETAILED DESCRIPTION

The invention provides a method for controlling transmission latency in a communications system, wherein the communications system is subject to a noise signal having at least a first noise phase and a second noise phase. The method includes determining a first bit rate for symbols transmitted during the first noise phase, and a second bit rate for symbols transmitted during the second noise phase. The first bit rate and the second bit rate are constrained such that a transmission latency does not exceed a pre-determined maximum allowed transmission latency. The method also includes transmitting symbols at the first bit rate during the first noise phase and at the second bit rate during the second noise phase. The method includes communicating the predetermined maximum allowed transmission latency via a message to a receiver of the communications system, and optionally configuring, in accordance with the first bit rate, a first bit allocation table for symbols transmitted during the first noise phase; and configuring, in accor-

dance with the second bit rate, a second bit allocation table for symbols transmitted during the second noise phase.

In one variant, the first noise phase corresponds to a first signal-to-noise ratio, and the second noise phase corresponds to a second signal-to-noise ratio. The second signal-to-noise ratio is higher than the first signal-to-noise ratio. The method also includes determining the second bit rate based on the second signal-to-noise ratio.

In another aspect, the method includes determining the first bit rate based on the second bit rate and the pre-determined maximum allowed transmission latency. The first bit rate is determined in accordance with the following equation:

$$R_1 = -R_2 * \left(\frac{S_2}{S_1}\right) * \frac{(latency * C + SymTime * S_1)}{(latency * C + SymTime * S_2)}$$

R_1 is the first bit rate. R_2 is the second bit rate. *Latency* is the predetermined maximum allowed transmission latency, and *SymTime* is a discrete multi-tone symbol duration for S_2 symbols of the second noise phase transmitted during a number C of noise clock cycles and S_1 symbols of the first noise phase transmitted during the number C of noise clock cycles.

The communications system is an adaptive rate communications system in one variant. In another variant, the communications system is an asymmetric digital subscriber line communications system or the communications system is an Annex C asymmetric digital subscriber line communications system.

The first noise phase is a far end cross talk noise phase. The second noise phase is a near end cross talk noise phase. The noise signal results from noise from a Time Compressed Multiplex - Integrated Switched Digital Network signal.

The first bit rate and the second bit rate are determined in accordance with the following equation:

$$latency = \frac{(R_1 - R_2) * T_2 * T_1}{R_1 T_1 + R_2 T_2}$$

Latency is the predetermined maximum allowed transmission latency. R_1 is the first bit rate. R_2 is the second bit rate. T_1 is a first time period corresponding to the first noise phase, and T_2 is a second time period corresponding to the second noise phase.

An apparatus for controlling transmission latency in a communications system, wherein the communications system is subject to a noise signal having at least a first noise phase and a second noise phase is also provided. The apparatus comprises a constrained rate receiver for determining a first bit rate for symbols transmitted during the first noise phase, and a second bit rate for symbols transmitted during the second noise phase. The first bit rate and the second bit rate are constrained such that a transmission latency does not exceed a pre-determined maximum allowed transmission latency.

A constrained rate transmitter for transmitting symbols at the first bit rate during the first noise phase and at the second bit rate during the second noise phase is also part of the apparatus. Fig. 2 shows a communications system with a constrained rate receiver 202 for determining constrained bit rates for controlling transmission latency, in accordance with an embodiment of the invention. In this embodiment, a constrained rate receiver 202 determines a first bit rate 203 for symbols transmitted during a first noise phase, and a second bit rate 204 for symbols transmitted during a second noise phase. The first and second noise phase may, for example, be the FEXT noise phase 103 and NEXT noise phase 104 of Fig. 1. The constrained rate receiver 202 determines the first bit rate 203 and second bit rate 204 so that they are constrained such that the latency of the transmission does not exceed a pre-determined maximum allowed transmission latency. A

constrained rate transmitter 201 is therefore able to transmit symbols 207 at the first bit rate 203 during the first noise phase and at the second bit rate 204 during the second noise phase, without exceeding the pre-determined maximum allowed transmission latency. The constrained rate transmitter 201 may transmit the pre-determined maximum allowed latency to the constrained rate receiver 202 via a message 206, which may be a message similar, for example, to the C-MSG1 message defined in the G.992.2 ITU standard.

The constrained rate transmitter further comprises a latency control transmitter for communicating the predetermined maximum allowed transmission latency via a message to the constrained rate receiver. Optionally, the constrained rate receiver further includes a first bit allocation table controller for configuring, in accordance with the first bit rate, a first bit allocation table for symbols transmitted during the first noise phase; and, a second bit allocation table controller for configuring, in accordance with the second bit rate, a second bit allocation table for symbols transmitted during the second noise phase.

The first noise phase corresponds to a first signal-to-noise ratio, and the second noise phase corresponds to a second signal-to-noise ratio, the second signal-to-noise ratio being higher than the first signal-to-noise ratio in one variant of the invention. The constrained rate receiver optionally further comprisesa second bit rate controller for determining the second bit rate based on the second signal-to-noise ratio. Alternatively, the constrained rate receiver further comprises a first bit rate controller for determining the first bit rate based on the second bit rate and the pre-determined maximum allowed transmission latency. The first bit rate controller comprises a controller for determining the first bit rate in accordance with the following equation:

$$R_1 = -R_2 * \left(\frac{S_2}{S_1}\right) * \frac{(latency * C + SymTime * S_1)}{(latency * C + SymTime * S_2)}$$

where R_1 is the first bit rate, R_2 is the second bit rate, *latency* is the predetermined maximum allowed transmission latency, and *SymTime* is a discrete multi-tone

symbol duration, for S_2 symbols of the second noise phase transmitted during a number C of noise clock cycles and S_1 symbols of the first noise phase transmitted during the number C of noise clock cycles.

The communications system is an adaptive rate communications system, is an asymmetric digital subscriber line communications system, or an Annex C asymmetric digital subscriber line communications system. The first noise phase is a far end cross talk noise phase. The second noise phase is a near end cross talk noise phase. The noise signal results from noise from a Time Compressed Multiplex - Integrated Switched Digital Network signal. The constrained rate receiver comprises a controller for determining the first bit rate and the second bit rate in accordance with the following equation:

$$latency = \frac{(R_1 - R_2) * T_2 * T_1}{R_1 T_1 + R_2 T_2}$$

where *latency* is the predetermined maximum allowed transmission latency, R_1 is the first bit rate, R_2 is the second bit rate, T_1 is a first time period corresponding to the first noise phase, and T_2 is a second time period corresponding to the second noise phase.

In another variant, the invention provides a constrained rate receiver for controlling transmission latency in a communications system, wherein the communications system is subject to a noise signal having at least a first noise phase and a second noise phase. The receiver is adapted to determine a first bit rate for symbols transmitted during the first noise phase, and a second bit rate for symbols transmitted during the second noise phase. The first bit rate and the second bit rate are constrained such that a transmission latency does not exceed a predetermined maximum allowed transmission latency.

In a further variant, a constrained rate transmitter in a communications system is provided, wherein the communications system is subject to a noise sig-

nal having at least a first noise phase and a second noise phase for transmitting symbols at the first bit rate during the first noise phase and at the second bit rate during the second noise phase, whereby the first bit rate and the second bit rate are determined in a constrained rate receiver described herein. A transmitter optionally includes a latency control transmitter for communicating the predetermined maximum allowed transmission latency via a message to a constrained rate receiver, and is optionally capable of receiving a message communicating the predetermined maximum allowed transmission latency.

A constrained rate receiver includes a first bit allocation table controller for configuring, in accordance with the first bit rate, a first bit allocation table for symbols transmitted during the first noise phase; and a second bit allocation table controller for configuring, in accordance with the second bit rate, a second bit allocation table for symbols transmitted during the second noise phase. The first noise phase optionally corresponds to a first signal-to-noise ratio, and the second noise phase corresponds to a second signal-to-noise ratio. The second signal-to-noise ratio is higher than the first signal-to-noise ratio.also includes a second bit rate controller for determining the second bit rate based on the second signal-to-noise ratio. The constrained rate receiver also optionally includes a first bit rate controller for determining the first bit rate based on the second bit rate and the pre-determined maximum allowed transmission latency. The first bit rate controller comprises a controller for determining the first bit rate in accordance with the following equation:

$$R_1 = -R_2 * \left(\frac{S_2}{S_1}\right) * \frac{(latency * C + SymTime * S_1)}{(latency * C + SymTime * S_2)}$$

where R_1 is the first bit rate, R_2 is the second bit rate, *latency* is the predetermined maximum allowed transmission latency, and *SymTime* is a discrete multi-tone symbol duration, for S_2 symbols of the second noise phase transmitted during a number C of noise clock cycles and S_1 symbols of the first noise phase transmitted during the number C of noise clock cycles.

The constrained rate receiver operates in a communications system which is an adaptive rate communications system. The communications system is optionally an asymmetric digital subscriber line communications system, or an Annex C asymmetric digital subscriber line communications system. The first noise phase is a far end cross talk noise phase. The second noise phase is a near end cross talk noise phase. The noise signal results from noise from a Time Compressed Multiplex - Integrated Switched Digital Network signal.

In yet a further variant, the constrained rate receiver further comprises a controller for determining the first bit rate and the second bit rate in accordance with the following equation:

$$latency = \frac{(R_1 - R_2) * T_2 * T_1}{R_1 T_1 + R_2 T_2}$$

where *latency* is the predetermined maximum allowed transmission latency, R_1 is the first bit rate, R_2 is the second bit rate, T_1 is a first time period corresponding to the first noise phase, and T_2 is a second time period corresponding to the second noise phase.

In yet another variant, the invention provides a signal in a communications system, wherein the communications system is subject to a noise signal having at least a first noise phase and a second noise phase. The signal includes a determined first bit rate for symbols transmitted during the first noise phase, and a second bit rate for symbols transmitted during the second noise phase. The first bit rate and the second bit rate are constrained such that a transmission latency does not exceed a pre-determined maximum allowed transmission latency. The signal also includes symbols transmitted at the first bit rate during the first noise phase and at the second bit rate during the second noise phase, such that the transmission latency in the communications system can be controllable.

Optionally, the signal includes a message representing the predetermined maximum allowed transmission latency. The symbols transmitted during the first noise phase from a first bit allocation table are configured in accordance with the first bit rate; and the symbols transmitted during the second noise phase from a second bit allocation table are configured in accordance with the second bit rate. The first noise phase corresponds to a first signal-to-noise ratio, and the second noise phase corresponds to a second signal-to-noise ratio. The second signal-to-noise ratio is higher than the first signal-to-noise ratio, such that the second bit rate is determined on the basis of the second signal-to-noise ratio. The first bit rate is determined on the basis of the second bit rate and the pre-determined maximum allowed transmission latency. The first bit rate is determined in accordance with the following equation:

$$R_1 = -R_2 * \left(\frac{S_2}{S_1}\right) * \frac{(latency * C + SymTime * S_1)}{(latency * C + SymTime * S_2)}$$

where R_1 is the first bit rate, R_2 is the second bit rate, *latency* is the predetermined maximum allowed transmission latency, and *SymTime* is a discrete multi-tone symbol duration, for S_2 symbols of the second noise phase transmitted during a number C of noise clock cycles and S_1 symbols of the first noise phase transmitted during the number C of noise clock cycles.

The signal is transmitted in a communications system that is an adaptive rate communications system, transmitted in a communications system that is an asymmetric digital subscriber line communications system, and/or transmitted in a communications system that is an Annex C asymmetric digital subscriber line communications system. The first noise phase is a far end cross talk noise phase. The second noise phase is a near end cross talk noise phase. The noise signal results from noise from a Time Compressed Multiplex - Integrated Switched Digital Network signal. The first bit rate and the second bit rate are determined in accordance with the following equation:

$$latency = \frac{(R_1 - R_2) * T_2 * T_1}{R_1 T_1 + R_2 T_2}$$

where *latency* is the predetermined maximum allowed transmission latency, R_1 is the first bit rate, R_2 is the second bit rate, T_1 is a first time period corresponding to the first noise phase, and T_2 is a second time period corresponding to the second noise phase.

In one variant, the FEXT and NEXT phase DMT symbols (Far End Cross-talk and Near End Cross-talk phase Discrete Multi-tone symbols) in an Annex C ADSL communications system are configured to have constrained bit rates, such that the system latency is kept within a specified limit. This solution employs the extra flexibility of Annex C processing, but constrains the values obtained for FEXT and NEXT bit maps such that the overall delay is kept to a specified amount.

One variant is referred to herein as a 'Constrained Rate Bitmap Mode' (CRBM). This permits the control of transmission latencies for an ADSL system operating in the presence of time varying TCM-ISDN (Time Compressed Multi-plex - Integrated Switched Digital Network) noise.

Fig. 3 shows a constrained rate receiver 302 for determining bit rates and bit allocation tables based on a signal-to-noise ratio and a maximum allowed trans-mission latency, in accordance with an embodiment of the invention. In this em-bodiment, the signal-to-noise ratio during one noise phase is higher than in the other noise phase. For example, with reference to Fig. 1, the signal-to-noise ratio during the NEXT noise phase 104 is optionally higher than the signal-to-noise ratio during the FEXT noise phase 103. In the embodiment of Fig. 3, the signal-to-noise ratio 314 of the worse phase (i.e. the phase with the higher signal-to-noise ratio, such as the NEXT noise phase 104 of Fig. 1) is used by a bit rate controller 309 to determine, for that phase, a bit rate 304 (here designated the second bit rate 304, determined by the second bit rate controller 309). Based on the second bit

rate 304 and the maximum allowed transmission latency 306, a first bit rate controller 308 determines the bit rate 303 (here designated the first bit rate 303) for the other phase (for example, the FEXT noise phase 103 of Fig. 1).

In Fig. 3, the first bit rate controller 308, for example, calculates the first bit rate 303 based on the equation:

$$R_1 = -R_2 * \left(\frac{S_2}{S_1}\right) * \frac{(latency * C + SymTime * S_1)}{(latency * C + SymTime * S_2)}$$

where R_1 is the first bit rate 303, R_2 is the second bit rate 304, *latency* is the predetermined maximum allowed transmission latency 306, and *SymTime* is a discrete multi-tone symbol duration, for a number of S_2 symbols of the second noise phase transmitted during the number of C noise clock cycles and the number of S_1 symbols of the first noise phase transmitted during the number of C noise clock cycles.

Once the first bit rate 303 and the second bit rate 304 are calculated, the embodiment of Fig. 3 uses first and second bit allocation table controllers 310 and 311 to calculate first and second bit allocation tables 312 and 313 for symbols transmitted during the first and second noise phases.

In order to derive the equation given above for calculating the first bit rate 303 in the embodiment of Fig. 3, we note that, in an Annex C solution, i.e. dual bit map operation, the consequence of a time varying noise environment is that of a time varying bit rate. To illustrate the effect of this, we consider a general system with two different bit rates that will be applied periodically in time, i.e. the bit rate R_1 is applied during a period T_1 and the bit rate R_2 which is smaller than R_1 is applied during a period T_2. Such a scenario is illustrated in Fig. 4.

The average bit rate is optionally computed according to the following equation:

$$R = (R_1T_1 + R_2T_2) / (T_1 + T_2).$$

Considering now - as shown in Fig. 5 - the buffer converting the average bit rate R to the instantaneous bit rates R_1 and R_2, the number of bits in the buffer decrease by $(R_1\text{-}R)*T_1$ bits during the period T_1 and increase again by $(R\text{-}R_2)*T_2$ bits during the period T_2. Thus, the size of this buffer must be at least

$$size\_buffer = \frac{(R_1 - R_2)}{T_1 + T_2} T_1 T_2 \quad bits \qquad \textbf{(1)}$$

and the jittering delay is equal to

$$latency = \frac{(R_1 - R_2)}{R_1T_1 + R_2T_2} T_2 T_1 \quad \text{sec} \qquad \textbf{(2)}$$

The jittering delay (latency) is 0 if both bit rates are equal, but otherwise it depends on the instantaneous bit rates and the duration of each period.

In the context of an Annex C system, the periods T_1 and T_2 depend on which cycle of the TTR clock the DMT symbol falls. To simplify an understanding of the process, we can consider that the number of FEXT and NEXT symbols can be fractional in each TTR clock cycle. Therefore, in this example we have 126 FEXT symbols and 214 NEXT symbols in a hyperframe of 340 useful symbols (excluding SYNC symbols), which span 34 TTR clock cycles. In one TTR clock cycle, we have on average, 126/34 FEXT symbols and 214/34 NEXT symbols. Rearranging Eq. 2 (and replacing R_1 with R_{FEXT} , R_2 with R_{NEXT}) gives the latency incurred by the Annex C rate converter as:

$$latency = \frac{(R_{FEXT} - R_{NEXT})}{126 * R_{FEXT1} + 214 * R_{NEXT}} \frac{126 * 214}{34}. SymTime\,s \quad \textbf{(3)}$$

where R_{FEXT} is the instantaneous bit rate of FEXT symbols (which equals n_{Fext}*4kbps), R_{NEXT} is the instantaneous bit rate of NEXT symbols (which equals n_{Next}*4kbps), and SymTime is the DMT symbol duration. As an example, with R_{FEXT}=4Mbps and R_{NEXT} =3Mbps, the latency is 0.17ms.

The amount of delay is completely determined by the mean bit rate and by the difference in bit rates between the FEXT and NEXT symbols. Thus, the amount of delay can be controlled by the receiver while computing the bit allocation tables for FEXT and NEXT.

In practice, the mean bit rate is determined by the SNR (Signal-to-Noise Ratio) measured in the worst phase (typically the NEXT phase) and by the maximum allowed latency. For example, if the NEXT phase SNR can accommodate a bit rate of 1MBps and the maximum allowed latency is 100μs, rearranging EQ. 3 we get

$$R_{FEXT} = -R_{NEXT} . \frac{214}{126} . \frac{(latency * 34 + SymTime * 126)}{(latency * 34 - SymTime * 214)} bs^{-1} \quad \textbf{(4)}$$

giving a FEXT bit rate of 1.18Mbps. In this case, the mean bit rate is 1.07Mbps, as opposed to a rate of 1Mbps that would be obtained using a single bit map mode approach. As demonstrated by the above example, the additional control leads to a significant improvement in attained bit rates over a pure Annex A solution, while maintaining an acceptable overall latency, as required by the specific appli-

cation. Equation 4 is expressed more generally as described in connection with the embodiment of Fig. 3.

In another variant, the constrained rate bit map (CRBM) approach offers a number of advantages over an Annex A solution, even in the case where the FEXT and NEXT bit maps are made equal. As shown in Fig. 6, in terms of bit rates, a CRBM approach appears to produce a poorer performance than a direct Annex A solution, when the FEXT and NEXT bit maps are made equal. This is, however, an incorrect assumption. A direct Annex A solution is likely to incur bit errors during NEXT symbols where the noise margin achieved will be lower than the target. In order to maintain the specified BER (Bit Error Rate) performance, the target margin will have to be increased, resulting in a similar bit rate to that computed by CRBM.

Moreover, although the bit rates in both phases are identical, the bit allocation maps need not be. TCM-ISDN noise is non-white. With respect to the scenario depicted in Fig. 7, an Annex A solution will derive an average spectral map of the NEXT and FEXT noise phase characteristics. This average will in no way be optimal in either context. A CRBM solution, in accordance with an embodiment of the invention, allows optimization of all aspects of the signal processing chain to the precise noise conditions measured in each phase. Thus, the bit rate performance is expected to exceed that which may be obtained by the Annex A approach.

Advantages of the preferred CRBM over standard Annex A and Annex C solutions, in accordance with an embodiment of the invention, include:

1. No requirement to have Annex A/C dynamically configurable.
2. The optimum rate versus latency is computed at run time.

3. The bit rates will be optimized to TCM noise environments. This will offer more robust transmission than can be obtained using Annex A bit rate computation algorithms.
4. The individual FEXT/NEXT bit maps will be optimized to the precise noise characteristics measured on each phase – under TCM noise conditions these will differ. Again, this is not achievable under Annex A modes of operation.

To illustrate that the additional control of CRBM in an embodiment of the invention can lead to a significant improvement in attained bit rates over a pure Annex A solution, while maintaining an acceptable overall latency, Fig. 8 summarizes the performance of a system with various amounts of latency, namely 1600 μs, 1500 μs, 1250 μs, 1000 μs, 750 μs, 500 μs, 250 μs and no latency (0 μs). The environment is 0.4 mm paper insulated cable with 24 TCM-ISDN noise and a –140dBm/Hz background noise and target margin 6dB. Note that for delay above 1.5735 ms, the NEXT capacity can be equal to 0, and the full bit rate of DBM is thus achievable. In all other cases the NEXT bit rates should be above 0. This explains the sharp drop at 2750m.

Thus the invention provides a method of, and system for, controlling the latency introduced by the Rate Converter buffering in Annex C ADSL systems operating in the presence of time varying TCM-ISDN noise. It has been demonstrated that in the presence of time varying noise TCM-ISDN, a dual bit map approach offers superior performance to a single bit map approach when the NEXT and FEXT symbol bit rates are constrained to be the same. Further, by introducing a latency control parameter we can improve on the attained bit rates while maintaining a specified overall bit rate.

Currently there are a number of proposals for extending the Japanese version of ADSL, known as ANNEX_C. The extensions put forward are Annexes I, J, and K. The invention applies in communications apparatus or protocols according to any such standards or future equivalents. Furthermore, there is proposed a new Annex A standard, known as G.992.3 (ADSL2) from the ITU, and various proposals for an Annex C version of this to which preferred embodiments could apply. In future Annex C developments, an additional latency parameter should be communicated via one of the messages, for example in the C-MSG1 as defined in the G992.2 ITU standard, permitting the benefits outlined in this document to be incorporated current and future standards.

In one variant the invention provides a method comprises for determining a first bit rate for symbols transmitted during the first noise phase, and a second bit rate for symbols transmitted during the second noise phase, the first bit rate and the second bit rate being constrained such that a transmission latency does not exceed a pre-determined maximum allowed transmission latency; and transmitting symbols at the first bit rate during the first noise phase and at the second bit rate during the second noise phase. The method optionally comprises communicating the predetermined maximum allowed transmission latency via a message to a receiver of the communications system. The method optionally comprises configuring, in accordance with the first bit rate, a first bit allocation table for symbols transmitted during the first noise phase; and configuring, in accordance with the second bit rate, a second bit allocation table for symbols transmitted during the second noise phase. If the first noise phase corresponds to a first signal-to-noise ratio, and the second noise phase corresponds to a second signal-to-noise ratio that is higher than the first signal-to-noise ratio. The second bit rate is determined based on the second signal-to-noise ratio; and the first bit rate is determined based on the second bit rate and the pre-determined maximum allowed transmission latency. In particular, the first bit rate is optionally determined in accordance with the following equation:

$$R_1 = -R_2 * \left(\frac{S_2}{S_1}\right) * \frac{(latency * C + SymTime * S_1)}{(latency * C + SymTime * S_2)}$$

where R_1 is the first bit rate, R_2 is the second bit rate, *latency* is the predetermined maximum allowed transmission latency, and *SymTime* is a discrete multi-tone symbol duration, for S_2 symbols of the second noise phase transmitted during a number C of noise clock cycles and S_1 symbols of the first noise phase transmitted during a number C of noise clock cycles.

In a further related variant, the communications system is an adaptive rate communications system; and in particular is an asymmetric digital subscriber line (ADSL) communications system, such as an Annex C ADSL system. The first noise phase may be a far end cross talk noise phase, and the second noise phase may be a near end cross talk noise phase. The noise signal may result from noise from a Time Compressed Multiplex - Integrated Switched Digital Network signal.

In another related method embodiment, the first bit rate and the second bit rate are determined in accordance with the following equation:

$$latency = \frac{(R_1 - R_2) * T_2 * T_1}{R_1 T_1 + R_2 T_2}$$

where *latency* is the predetermined maximum allowed transmission latency, R_1 is the first bit rate, R_2 is the second bit rate, T_1 is a first time period corresponding to the first noise phase, and T_2 is a second time period corresponding to the second noise phase.

A skilled reader will appreciate that, while the foregoing has described what is considered to be the best mode and where appropriate other modes of performing the invention, the invention is not limited to specific apparatus configurations or method steps disclosed in this description of the preferred embodiment. Those skilled in the art will also recognise that the invention has a broad range of applications, not necessarily connected with ADSL or even DSL communications systems, and the embodiments admit of a wide range of modifications without departing from the inventive concepts.